Assessment of Corn Pollen as a Food Source for Two Tephritid Fruit Fly Species

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ABSTRACT The melon fly, *Bactrocera cucurbitae* (Coquillett) is a serious pest of cucurbit crops. Although melon fly females oviposit in cucurbit crops, both males and females are frequently associated with a range of nonhost plants, including both crops such as corn (*Zea mays* C. Linnaeus) and wild plants such as castor bean (*Ricinus communis* C. Linnaeus) that occur within the cropping area or along the crop borders. This association with nonhost plants has been used for control purposes through the technique of spraying protein baits incorporating a toxicant on these nonhost plants. Association of melon flies to corn has not been reported to be tied to any phenological stage of corn. We report field studies that show that melon flies, as well as oriental fruit flies, *B. dorsalis* (Hendel), may show increased population levels in corn at the time of, and subsequent to, flowering and pollen shed and suggest that this population increase may be tied to pollen consumption. Before this, pollen had not been reported to be an important food source for the tropical *Bactrocera* spp.

KEY WORDS *Bactrocera cucurbitae*, *Bactrocera dorsalis*, natural food sources, *Zea mays*, pollen, cucurbits

THE MELON FLY, *Bactrocera cucurbitae* (Coquillett), is a serious pest of cucurbit crops (cucumbers, squash, melons, etc.) in many Asia countries, several African countries, and several Pacific islands including Guam and the Hawaiian Islands (White and Elson-Harris 1992). Although melon fly females oviposit in cucurbit crops, both males and females have been found to be frequently associated with a range of nonhost plants. These nonhost plants include crops such as corn (*Zea mays* C. Linneaus) and wild plants such as castor bean (*Ricinus communis* C. Linneaus) that occur within the cropping area or along crop borders (Nishida and Bess 1950, 1957). This association with nonhost plants has been used for control purposes by spraying protein baits incorporating a toxicant on these nonhost plants. With clean cultivation (i.e., no attractive nonhost plants permitted to grow within the cropping area), this procedure leads to border spraying. One border often planted for this purpose is corn (Ebeling et al. 1953, Nishida and Bess 1957). While doing routine monitoring of melon fly populations on a diversified crop farm on the island of Kauai, we noticed that the melon fly population level peaked, as measured by catches in protein bait traps maintained in a planting of corn, in the midst of the corn life cycle. This peak was subsequently observed in other corn fields that were bordered by melon fly host plants and it seemed that the peak melon fly population levels were associated with the time of corn pollen shed.

Natural food sources of adult tephritid fruit flies have been reported to include aphid and coccid honeydew, juices and tissues of damaged or decaying fruit, plant sap, nectar from flowers and extrafloral nectaries, bird feces (Nishida 1958, Christenson and Foote 1960, Bateman 1972, Tsitsipis 1989, Hendrichs et al. 1991), and leaf surface bacteria (Drew et al. 1983). Pollen has also been found to be a food source for certain tephritid fruit fly species. *Dacus oleae* (Gmelin) survived and reproduced when fed pollen from five different wind pollinated plant species (Tsiropoulos 1977). *Rhagoletis pomonella* (Walsh) adults showed good survival on a diet of unidentified windblown pollen and sucrose. However, they had a low rate of egg production (Hendrichs et al. 1993). Pollen has not, however, been reported as an important food source for the tropical *Bactrocera* spp.

In this paper, we present evidence in support of the potential importance of corn pollen as a dietary food item for *Bactrocera cucurbitae* and for *B. dorsalis* (Hendel), another tephritid fruit fly species which is also commonly found on corn plants, and discuss some of the potential implications of this finding for control purposes.

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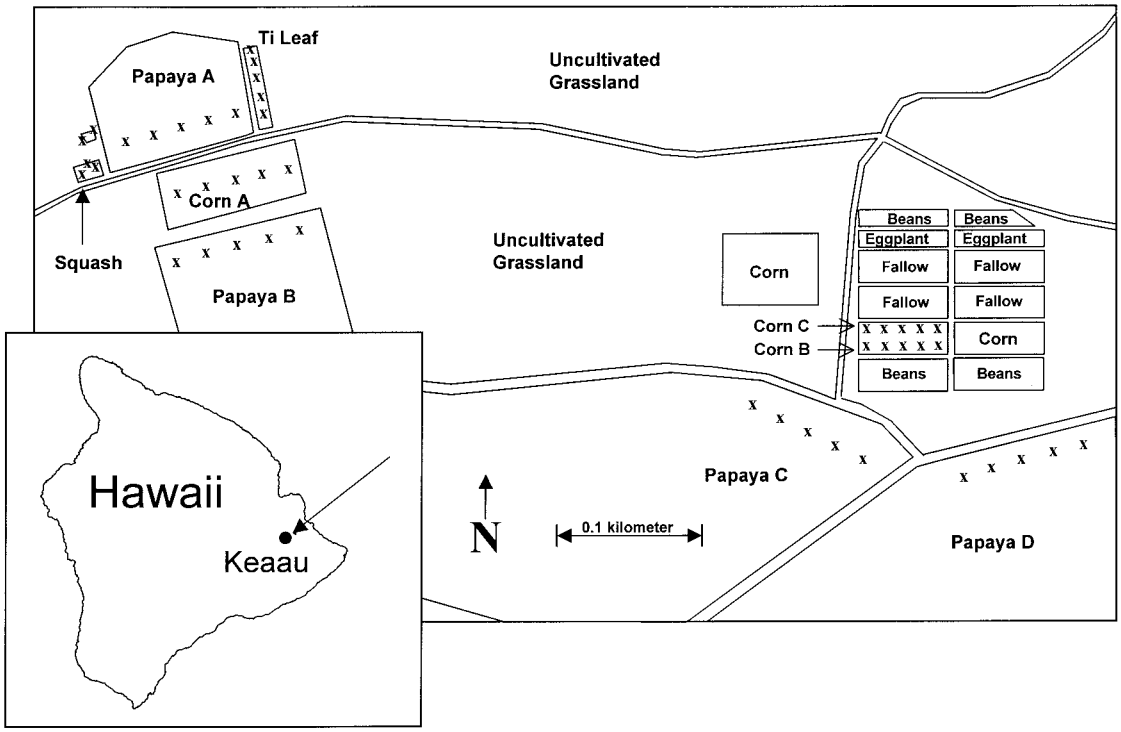

Fig. 1. Site of study showing relative locations of crops present. Trap locations are indicated by 'x'.

Materials and Methods

Survival Tests. Melon flies and oriental fruit flies used for dietary tests were obtained as pupae from a laboratory colony at the USDA-ARS, U.S. Pacific Basin Agricultural Research Center (PBARC) in Honolulu, HI. Fruit fly pupae were kept in an insectary at 24–27°C, 65–70% RH, and a photoperiod of 12:12 (L:D), with only agar available (a water source) upon adult emergence. On 24 January 2000, within 3 d of adult emergence, flies were transferred from emergence chambers to feeding chambers (2-liter transparent plastic cups [Sweetheart Cup Co., Chicago, IL] with 20 females per cup). One of six diets was then provided: (1) agar and sucrose (two cubes of sugar [99.96% sucrose; California and Hawaiian Sugar Co., Crockett, CA]); (2) agar, sucrose and 0.5 g ICN protein yeast hydrolysate (Enzymatic, United States Biochemical Corporation, Cleveland, OH); (3) agar, sucrose and 0.5-g corn pollen (Sigma, St. Louis, MO); (4) agar, 0.5-g ICN protein yeast hydrolysate; (5) agar, 0.5-g corn pollen; or (6) agar, sucrose and a piece of 'protein cake' consisting of three parts sucrose, one part protein yeast hydrolysate, and 0.5 part torula yeast (Lake States Division, Rhinelander Paper Co., Rhinelander, WI). Diet number six is routinely used as an adult maintenance diet at PBARC (Hilo, HI). Five chambers of each diet were established for each species. Numbers of dead flies in each chamber were recorded daily (Monday–Friday) for the first 2 wk and twice a week thereafter until all chambers had at least 50% mortality. Fresh food and clean chambers were provided at least every two months (first change = 16 March 2000) and adult survival was monitored over 120 d.

Population Assessment. On 18 January 2000, yellow-bottom plastic dome traps (Biosys, Inc., Palo Alto, CA), baited with 10% (wt:wt) Provesta 621 (an autolyzed yeast extract obtained from Integrated Ingredients [Bartlesville, OK]), 3% (wt:wt) borax, and 87% (wt:wt) water, were set out in three corn fields and in surrounding agricultural areas which could support melon fly and oriental fruit fly populations (Fig. 1). The first corn field (corn A) had one long narrow patch of corn (0.064 ha) with papaya (*Carica papaya* C. Linnaeus) orchards on either side. The corn and orchards were separated by plowed, unplanted field and field borders of weedy grasses, herbaceous plants, and sugar cane (*Saccharum officinarum* C. Linnaeus). The papaya orchard on the north side had a patch of pumpkin squash (*Cucurbita moschata* [A. Duchesne *ex* J. deLamarck.] A. Duchesne *ex* J. Poiret) at one end and ti plants (*Cordyline terminalis* [C. Linnaeus] K. Kunth) at the other end. On 18 January, 2000, five traps were placed in corn A, with sets of five traps also set in each of the bordering papaya orchards and in the ti leaf patch. On 4 February 2000, five additional traps were placed in the squash patch. Once traps were in place, they were serviced twice a week, with bait solution replaced every 2 wk. The second (corn B [0.16 ha]) and third (corn C [0.14 ha]) corn fields were separated by ≈4.6 m. In corn B, 5 traps were placed 5 rows in from the edge closest to the nearby

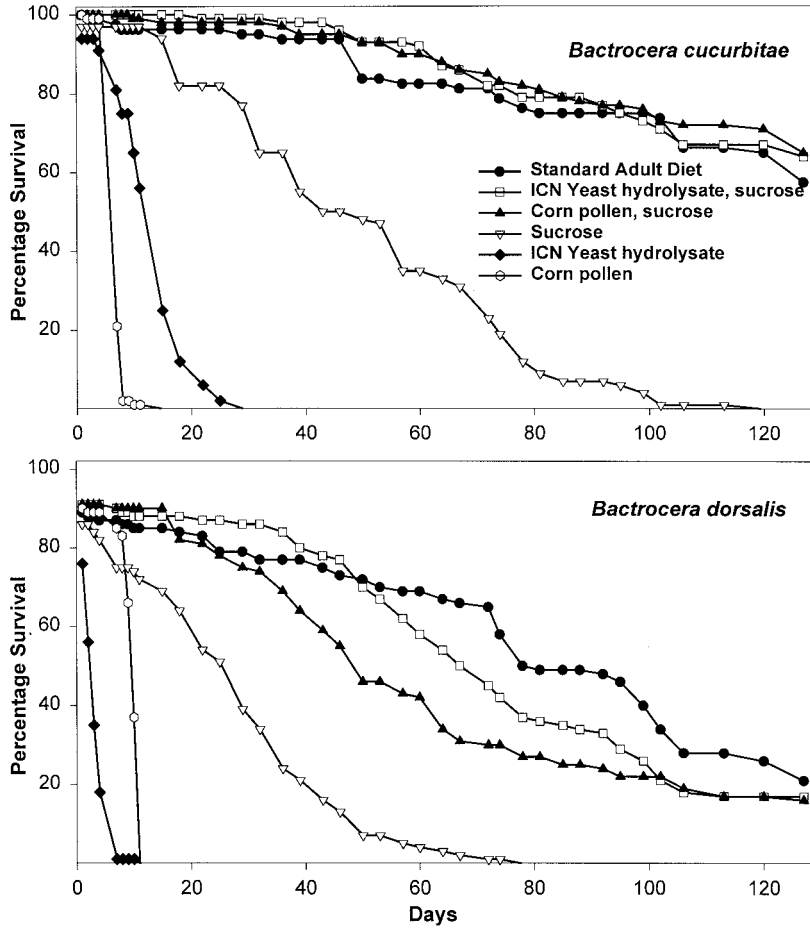

Fig. 2. Percentage survival of *B. curcurbitae* and *B. dorsalis* adults fed on one of six different diets.

papaya orchard. In corn C, five traps were placed five rows in from the edge farthest away from the papaya orchard. A total of 10 traps were placed in the papaya orchard; 5 set out on 18 January and 5 set out on 25 January. All traps in corn A, B, and C were removed on 28 March, 2000, after corn harvest and just before plowing the fields. Traps in the surrounding areas were removed on 7 April 2000, about 1 wk after the corn in both fields had been plowed under. On a weekly basis, the stage of corn phenology was documented and measurements were taken to estimate corn leaf area. The four phenological stages were whorl, flowering, pollinating, and dry silk (Naranjo and Sawyer 1988). The whorl stage extended until the first emergence of tassels. The flowering stage extended from the first emergence of tassels above the leaf whorl until silks were completely dried. The pollinating stage, a substage of the flowering stage, began when at least 50% of the monitored plants were actively shedding pollen. The dry silk stage began when the silks were completely dry on at least 50% of the monitored plants. Five plants near each trap were monitored to determine the overall stage of development. Leaf area was calculated as an average of the leaf areas of five plants, one plant near each trap. Leaf area (A) was approximated by the sum of the products, from each leaf, of leaf length (L), maximum leaf width (W), and 0.75, a correction factor (C) generally appropriate for corn ($A = \Sigma CLW$; Zhang and Brandle 1997).

Fecundity Tests. Adult *B. cucurbitae* recovered from papayas infested by adults which had emerged from field-collected papayas were used in tests of the contribution of corn pollen to fecundity. Adults were maintained on 0.5 g ICN + sucrose, 0.5 g corn pollen + sucrose, or sucrose alone with fresh ICN and fresh corn pollen added weekly. Sources of ICN, corn pollen, and sucrose were the same as listed above for survivorship tests. All treatments included a source of water. When flies were 7 wk old, four sets of 20 females were prepared from each diet regime and placed into four separate 25 by 25 by 25 cm screened cages. Papayas were obtained at a green to color break stage, to minimize chance of prior infestation (Liquido et al. 1989), and held in a fly-free area until ripe. At 9:00 a.m. on the test day, a ripe papaya, into which 20 (1-mm diameter) holes had been poked, was introduced into each cage. Flies were permitted to oviposit in the fruits

Table 1. Results of ANOVAs on square root transformed adult *B. cucurbitae* trap catch in corn plants of three different phenology stages

Corn trap set	Fly sex	*F*	df	*P*	Corn phenology stage	Average Flies per trap per day
A	♂	121.9	2,97	<0.0001	Dry silk	4.2a
					Flowering	1.7b
					Whorl	0.3c
	♀	137.3	2,97	<0.0001	Dry silk	6.0a
					Flowering	2.4b
					Whorl	0.4c
	♂ + ♀	163.9	2,97	<0.0001	Dry silk	10.2a
					Flowering	4.1b
					Whorl	0.7c
B	♂	44.2	2,97	<0.0001	Dry silk	3.0a
					Flowering	1.4b
					Whorl	0.4c
	♀	37.5	2,97	<0.0001	Dry silk	3.4a
					Flowering	2.0b
					Whorl	0.6c
	♂ + ♀	49.2	2,97	<0.0001	Dry silk	6.4a
					Flowering	3.4b
					Whorl	0.9c
C	♂	31.5	2,97	<0.0001	Flowering	1.1a
					Dry silk	1.0a
					Whorl	0.3b
	♀	41.2	2,97	<0.0001	Flowering	1.7a
					Dry silk	1.2b
					Whorl	0.3c
	♂ + ♀	54.2	2,97	<0.0001	Flowering	2.8a
					Dry silk	2.2a
					Whorl	0.6b

Untransformed average trap catch data are presented. Trap catches followed by the same letter are not significantly different at the $\alpha = 0.05$ level.

for 24 h. From the time of sexing to the end of the oviposition period, all flies were maintained on sucrose and water only. Upon completion of the oviposition period, the fruits were removed from the cages and placed individually in plastic containers with screened lids containing clean sand to serve as an environment for pupation and adult eclosion of tephritid fruit flies. Two weeks later, pupating larvae and pupae were removed from the sand and fruit and transferred to small plastic cups (0.25 liter) containing a small amount of sand for pupation.

Statistical Analyses. Percentage survival data were arcsine transformed (θ = arcsin$\sqrt{p}$, where p is the proportion of flies which survived) before testing at 60 and at 120 d for treatment differences using analysis of variance (ANOVA), with Waller-Duncan K-ratio *t*-test for separation of means. Trap catch data were square root transformed and then grouped according to crop phenology stage (whorl, flowering, dry silk) before testing for population differences at each phenology stage using ANOVA, with Waller-Duncan K-ratio *t*-test for separation of means. Comparison of population levels of *B. dorsalis* and *B. cucurbitae* in corn areas and in papaya areas was made by using paired *t*-tests of square root transformed trap catch. Numbers of individuals infesting fruits in the fecundity tests were square root transformed, after division by fruit weight, before testing for treatment differences using ANOVA, with Waller-Duncan K-ratio *t*-test for separation of means.

Results

Survival Tests. Average percentage survival of *B. cucurbitae* and *B. dorsalis* adults over time is presented in Fig. 2. There were significant differences in adult survival of both species at both 60 d and 120 d (*B. cucurbitae:* 60 d [$F = 120.1$, df = 5, 23, $P < 0.001$]; 120 d [$F = 51.1$, df = 5, 23, $P < 0.001$]; *B. dorsalis:* 60 d [$F = 29.1$, df = 5, 24, $P < 0.001$]; 120 d [$F = 22.8$, df = 5, 24, $P < 0.001$] based on differences in diets. For both species, long-term survival was poor without a sugar source in the diet. Survival with corn pollen replacing a protein source, however, differed between the species. For *B. cucurbitae*, there was no significant difference in survivorship between the diet with corn pollen and sucrose (90.0 ± 4.5; 71.0 ± 9.9) and the standard adult diet (82.5 ± 6.5; 65.0 ± 9.5) or a diet with ICN yeast hydrolysate and sucrose (92.0 ± 2.0; 67.0 ± 9.3) at either 60 d or at 120 d, respectively. For *B. dorsalis*, survivorship was significantly less on the diet of corn pollen and sucrose (42.0 ± 9.9) than on the standard adult diet (69.0 ± 3.7) but not significantly different than on the diet with ICN yeast hydrolysate and sucrose (58.0 ± 10.7) at 60 d, but there was no significant difference in survivorship among these treatments at 120 d (17.0 ± 3.0, 26.0 ± 8.6, 17.0 ± 4.6, respectively).

Population Assessment. *Bactrocera cucurbitae.* There were significant differences in trap catch of *B. cucurbitae* adults relative to corn phenology stage (Table 1; Figs. 3 and 4). Based on Corn A and Corn B traps, trap catch at the dry silk stage was significantly greater than at the flowering stage and catch at the flowering stage was significantly greater than at the whorl stage for males, for females, and for total flies. With Corn C traps, which were further away from the papaya orchard, female trap catch was significantly greater at the pollen-shed stage than at the dry silk stage which was significantly greater than at the whorl stage. The same trend was found for males and for total flies, but catch was not significantly different between flowering and dry silk stages. Even as fruit damage by *B. cucurbitae* is typically greater at field edges (Nishida and Bess 1957), the higher trap catch of *B. cucurbitae* in Corn B than in Corn C traps at the start of the dry silk stage suggests that flies may tend to feed more toward the edge of the corn field nearer to the nearest papaya orchard, their presumed host fruit area.

An increase in total *B. cucurbitae* trap catch in ti leaf traps was observed near the beginning of the dry silk stage of the corn in which the corn A traps were placed (Fig. 3). There was no visual change in ti plant phenology that might impact their attractiveness to tephritid fruit flies over the course of the trapping period. This increase in trap catch may indicate a general *B. cucurbitae* population increase that contributed to the increased trap catch in Corn A. However, the movement of flies in response to pollen availability seems to be the primary reason for increased Corn A trap catch. The increased trap catch in Papaya D near

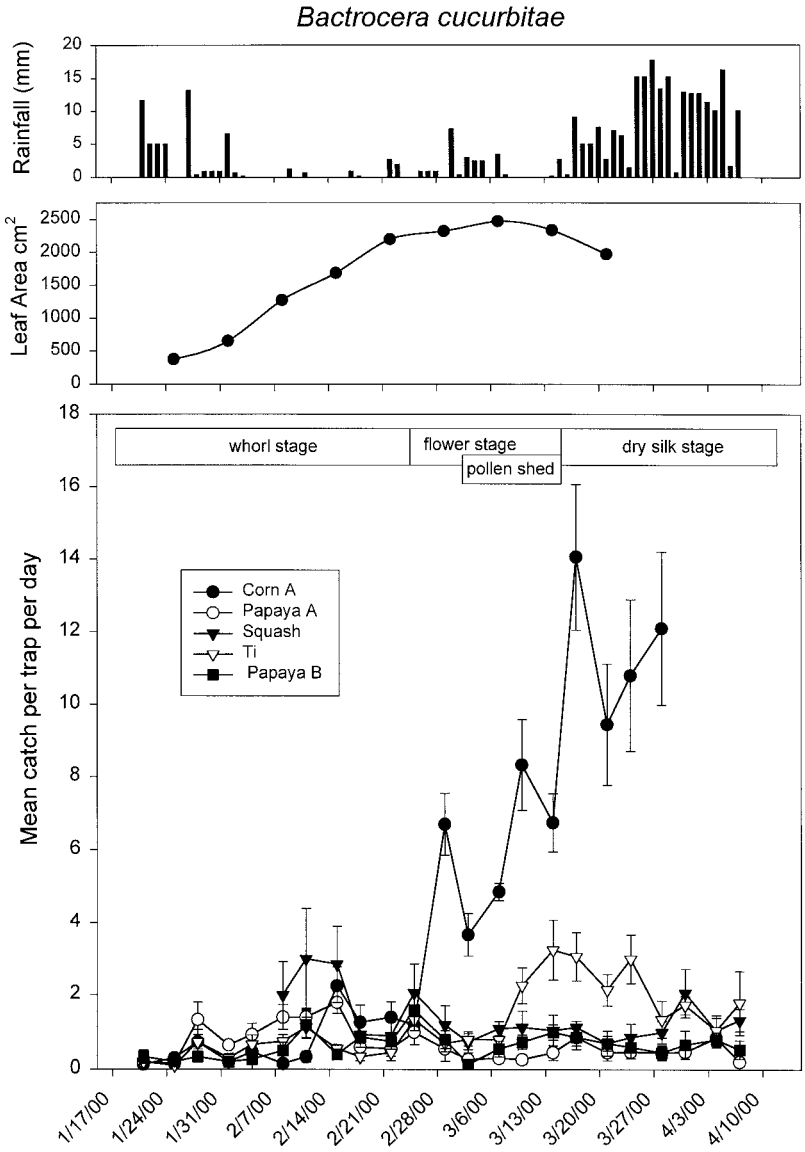

Fig. 3. Average catch per trap per day of *B. cucurbitae* adults recovered from Corn A, and crops in its vicinity, throughout the change in corn phenology from early whorl stage to the end of the dry silk stage. Also presented are rainfall and the change in corn leaf area over this time period.

the beginning of the flowering stage of Corn B and Corn C (Fig. 4) may similarly reflect a general population increase that could have contributed to the increased catch in Corn B and Corn C. However, this increase seems to primarily result from attractiveness of the corn. The increased attractiveness of the corn may draw flies from a fairly broad area of the papaya orchard, effectively concentrating the flies.

Bactrocera dorsalis. Significant differences in trap catch among corn phenology stages were found only in Corn A and for females in Corn B (Table 2; Figs. 5 and 6). Corn A trap catch at the dry silk stage was significantly greater than at the flowering stage which was significantly greater than at the whorl stage for males, for females, and for total flies. For females in Corn B, trap catch was significantly greater at the dry silk stage than at either the flowering or the whorl stages. There were no significant differences in trap catch for males or total flies in Corn B traps or for males, females, or total flies in Corn C traps. As with *B. cucurbitae*, there may have been a general *B. dorsalis* population increase as trap catch increased in Papaya A, Papaya B and ti leaf areas toward the end of the flowering stage of Corn A (Fig. 5). This increase, though, was greater in Corn A traps than in the papaya areas, suggesting increased movement of flies to corn.

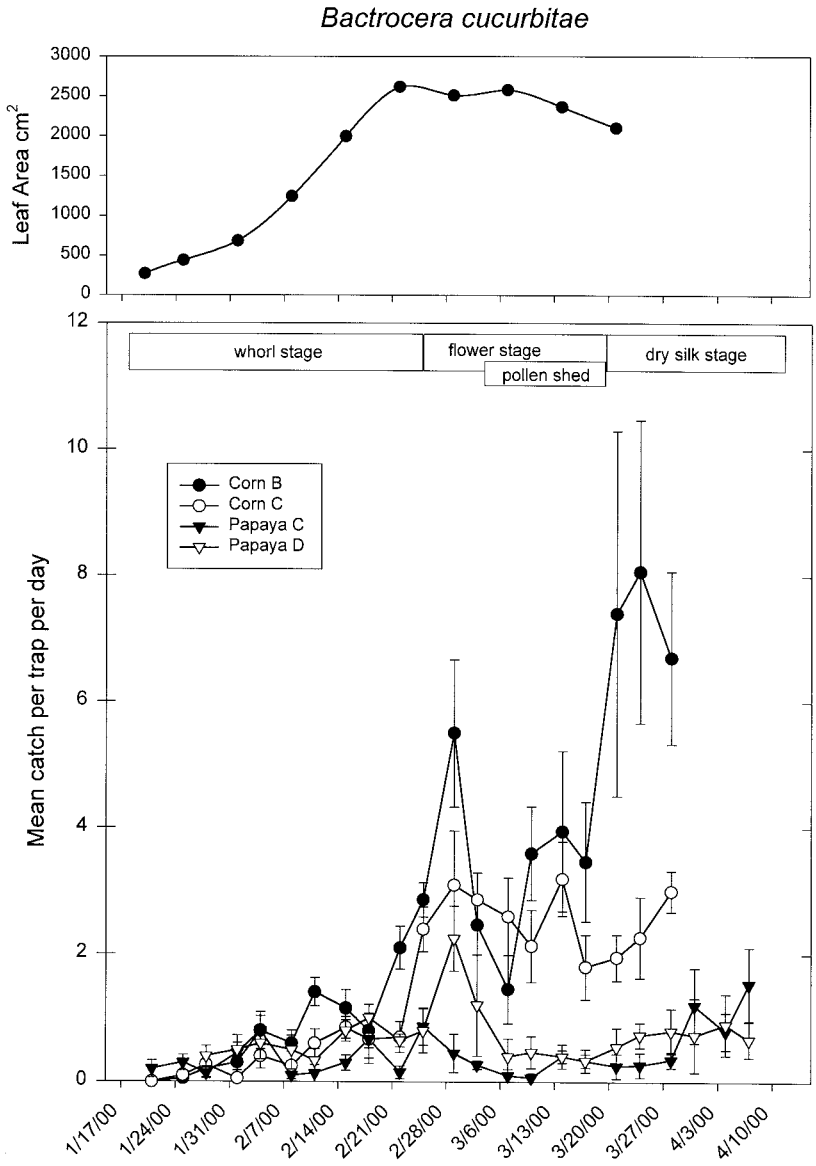

Fig. 4. Average catch per trap per day of *B. cucurbitae* adults recovered from corn B and corn C, and papaya orchards in their vicinity, throughout the change in corn phenology from early whorl stage to the end of the dry silk stage. Also presented is the change in corn leaf area, averaged from Corn B and Corn C, over this time period.

Bactrocera dorsalis trap catch averaged greater than *B. cucurbitae* catch in Papaya A (1.46 versus 0.68 flies/trap/d, respectively) and Papaya B (0.99 versus 0.63 flies/trap/d, respectively). Average *B. dorsalis* trap catch, however, in the associated corn A averaged less than that of *B. cucurbitae* at the whorl stage (0.25 versus 0.72 flies/trap/d, respectively), flowering stage (1.29 versus 4.10 flies/trap/d, respectively), and at the dry silk stage (5.50 versus 10.25 flies/trap/d, respectively). Results of the paired *t*-tests showed that these differences were significant for female and total flies, but not male flies in both Papaya A and Papaya B and were significant for male, female, and total flies in corn A at all three phenological stages. Results of trap catches in Corn B and Corn C showed the same trend, but were less conclusive because the *B. cucurbitae* population exceeded the *B. dorsalis* population in Papaya D (Table 3). Overall, these results suggest that *B. dorsalis* is less prone to roosting and feeding in corn fields than *B. cucurbitae.*

Significance of Leaf Area to Population Build-Up. Populations of both *B. cucurbitae* and *B. dorsalis* showed positive correlations with corn leaf area in all three corn fields. Correlations were higher for *B. cucurbitae* in all three corn fields (Corn A: $r^2 = 0.60, 0.50$, respectively; Corn B: $r^2 = 0.60, 0.19$; Corn C: $r^2 = 0.63, 0.21$) using data

Table 2. Results of ANOVAs on square root transformed adult *B. dorsalis* trap catch in corn plants of three different phenology stages

Corn trap set	Fly sex	*F*	df	*P*	Corn phenology stage	Average Flies per trap per day
A	♂	49.6	2,97	<0.0001	Dry silk	1.8a
					Flowering	0.6b
					Whorl	0.1c
	♀	105.8	2,97	<0.0001	Dry silk	3.7a
					Flowering	0.6b
					Whorl	0.1c
	♂ + ♀	88.3	2,97	<0.0001	Dry silk	5.5a
					Flowering	1.3b
					Whorl	0.2c
B	♂	2.2	2,97	0.120	Whorl	0.4a
					Dry silk	0.2a
					Flowering	0.2a
	♀	3.5	2,97	0.033	Dry silk	0.3a
					Whorl	0.1b
					Flowering	0.1b
	♂ + ♀	1.6	2,97	0.215	Whorl	0.6a
					Dry silk	0.5a
					Flowering	0.3a
C	♂	0.5	2,97	0.612	Whorl	0.2a
					Dry silk	0.2a
					Flowering	0.2a
	♀	1.4	2,97	0.240	Dry silk	0.2a
					Whorl	0.2a
					Flowering	0.1a
	♂ + ♀	1.8	2,97	0.164	Dry silk	0.4a
					Whorl	0.4a
					Flowering	0.3a

Untransformed average trap catch data are presented. Trap catches followed by the same letter are not significantly different at the $\alpha = 0.05$ level.

up to the time of peak recorded leaf area. However, fly populations typically continued to increase beyond the time of peak leaf area (except for *B. dorsalis* in Corn B and Corn C). The timing of the population increases, combined with the analyses presented above and in Tables 2 and 3, suggest that the increases are not tied only to increased shelter for roosting but also may be related to increased feeding opportunity.

Fecundity Tests. There was a significant difference in fecundity among treatments ($F = 73.2$, df = 2,11, $P < 0.0001$). Fecundity was significantly greater among flies in the ICN protein-based diet (19.8 individuals/female/kg fruit) than in either the corn pollen-based diet (0.062 individuals/female/kg fruit) or in the sucrose only diet (0.0 individuals/female/kg fruit). The difference in fecundity between the latter two treatments was not significant.

Discussion

Although pollen has been reported as food of tephritid fruit flies, it typically has not received much attention. Adult *D. oleae* flies fed a diet of sucrose with 10% (wt:wt) pollen from *Olea europaea* C. Linnaeus (olive) survived as well as flies fed on a standard adult diet of yeast hydrolyzate and sucrose. However, egg production per female per day was significantly less on the diet containing olive pollen. Both survival and fecundity tended to be less for other pollen tested (Tsiropoulos 1977). Similarly, *R. pomonella* adults fed a diet of various pollen and sucrose showed comparable survivorship to adults fed on a diet of yeast hydrolysate and sucrose, but the fecundity (eggs per female per day) was significantly less (Hendrichs et al. 1993). Our results showed good survivorship of melon fly adults when fed a diet of corn pollen and sugar, but less so for oriental fruit fly. Fecundity of melon fly was poor when fed on a diet of corn pollen and sucrose, as had been found by Hendrichs et al. (1993) for

Table 3. Results of paired *t*-tests comparing trap catches of *B. dorsalis* and *B. cucurbitae* in papaya and corn fields throughout the study

Crop	Mean variable	Difn	*t*-value	*P*	*n*	Crop	Mean variable	Difn	*t*-value	*P*	*n*
Papaya A	males	−0.10	−1.09	0.278	115	Papaya D	males	0.14	4.80	<0.0001	105
	females	−0.68	−4.27	<0.0001	115		females	0.34	6.17	<0.0001	105
	total	−0.78	−3.65	0.0004	115		total	0.48	7.19	<0.0001	105
Papaya B	males	−0.033	−1.07	0.288	115	Corn A - whorl	males	0.16	2.42	0.019	50
	females	−0.32	−3.69	0.0003	115		females	0.32	4.24	<0.0001	50
	total	−0.36	−3.40	0.0009	115		total	0.47	4.52	<0.0001	50
Papaya C	males	−0.0043	0.09	0.926	115	Corn A - flowering	males	1.05	6.00	<0.0001	20
	females	−0.053	−1.22	0.226	115		females	1.77	6.90	<0.0001	20
	total	−0.057	−1.00	0.318	115		total	2.81	8.31	<0.0001	20
Corn A - dry silk	males	2.40	7.21	<0.0001	30	Corn C - whorl	males	0.021	0.47	0.639	55
	females	2.35	4.60	<0.0001	30		females	0.13	2.46	0.0173	55
	total	4.75	6.55	<0.0001	30		total	0.15	1.75	0.0862	55
Corn B - whorl	males	−0.058	0.11	0.914	55	Corn C - flowering	males	0.92	7.70	<0.0001	25
	females	0.42	5.80	<0.0001	55		females	1.59	12.76	<0.0001	25
	total	0.36	4.14	0.0001	55		total	2.51	14.01	<0.0001	25
Corn B - flowering	males	1.17	7.96	<0.0001	25	Corn C - dry silk	males	0.81	5.80	<0.0001	20
	females	1.91	11.36	<0.0001	25		females	1.01	5.11	<0.0001	20
	total	3.08	12.15	<0.0001	25		total	1.82	7.03	<0.0001	20
Corn B - dry silk	males	2.80	8.90	<0.0001	20						
	females	3.07	9.32	<0.0001	20						
	total	5.87	10.22	<0.0001	20						

Catch results (flies/trap/day) were square root transformed before analysis, but untransformed differences (*B. cucurbitae* - *B. dorsalis*) are presented here.

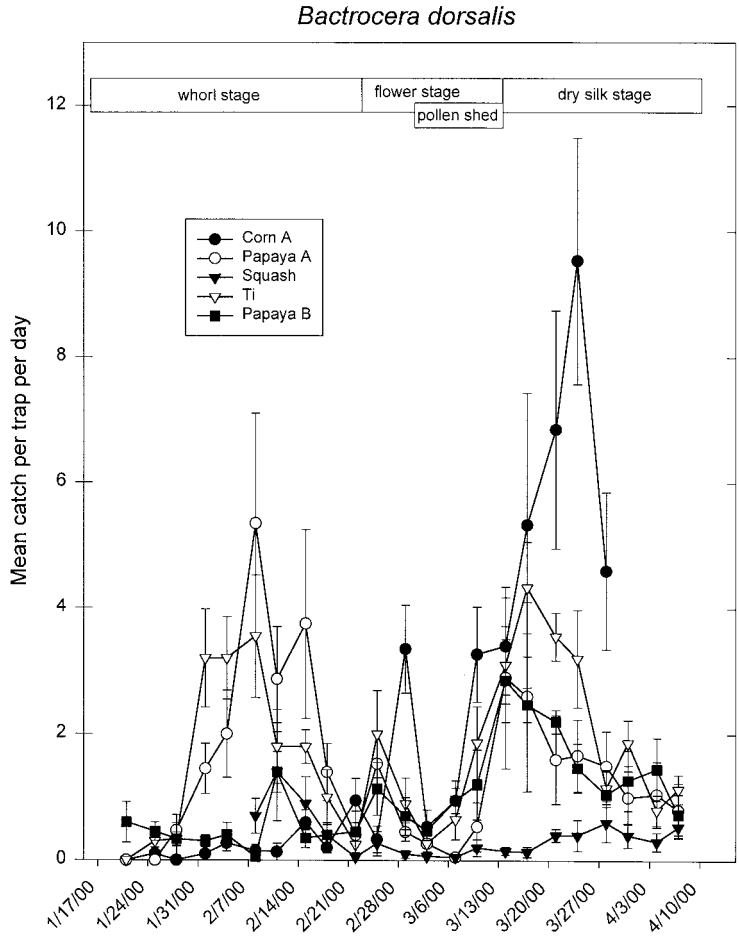

Fig. 5. Average catch per trap per day of *B. dorsalis* adults recovered from Corn A, and crops in its vicinity, throughout the change in corn phenology from early whorl stage to the end of the dry silk stage.

R. pomonella. Although there was no significant difference in fecundity between a diet of corn pollen and sugar and a diet of sugar only, it is important to note that females fed corn pollen produced some progeny, while there was none with sugar only.

Melon fly has been reported to feed on exudates from extrafloral nectaries of castor bean and several other plants (Nishida 1958). Extrafloral nectary exudate of castor bean contains amino acids, glucose and fructose (Baker et al. 1978). This exudate, or possibly Homopteran-produced honeydew, could provide both a sugar source and some amino acids to supplement nutrients obtained through pollen consumption. In tests with the predatory mite, *Iphiseius degenerans* (Berlese), van Rijn and Tanigoshi (1999) found that castor bean pollen consumption, in conjunction with castor bean extrafloral nectary exudate, permitted oviposition. These results suggest that a melon fly diet which included extrafloral nectary exudate and pollen could contribute to melon fly survival and fecundity in the field. The resulting fecundity in the field could be greater than found here on the corn pollen plus sucrose diet, because field sugar sources (e.g., extrafloral nectary exudate) could include amino acids that were not present in our provided sucrose and fresh corn pollen could contain nutrients that are lost in the processing of corn pollen for commercial marketing.

Although the use of corn borders has often been advocated as sites for localizing bait sprays to control melon fly, the authors are not aware of any literature indicating the distance corn borders can be placed away from a host crop and still draw melon flies. Knowledge of the distance of movement of melon flies to feeding/roosting areas is important in planning control efforts. Kazi (1976) recorded melon flies feeding on extrafloral nectary exudate of cowpeas (*Vigna sinensis* [C. Linnaeus] Savi *ex* Hassk) growing almost 100 m away from the nearest cucurbit plots and noted finding flies roosting on a number of different nonhost plants "not beyond 180 m distance from the cucurbitaceous fields." In this research, the nearest fruit host to the corn (papaya) was ≈31 m away in corn A and 46 m away in corn B and still attracted both melon flies and oriental fruit flies, particularly during pollen-shed stage or later. The increased attraction during pollen-shed stage or later has not previously been reported.

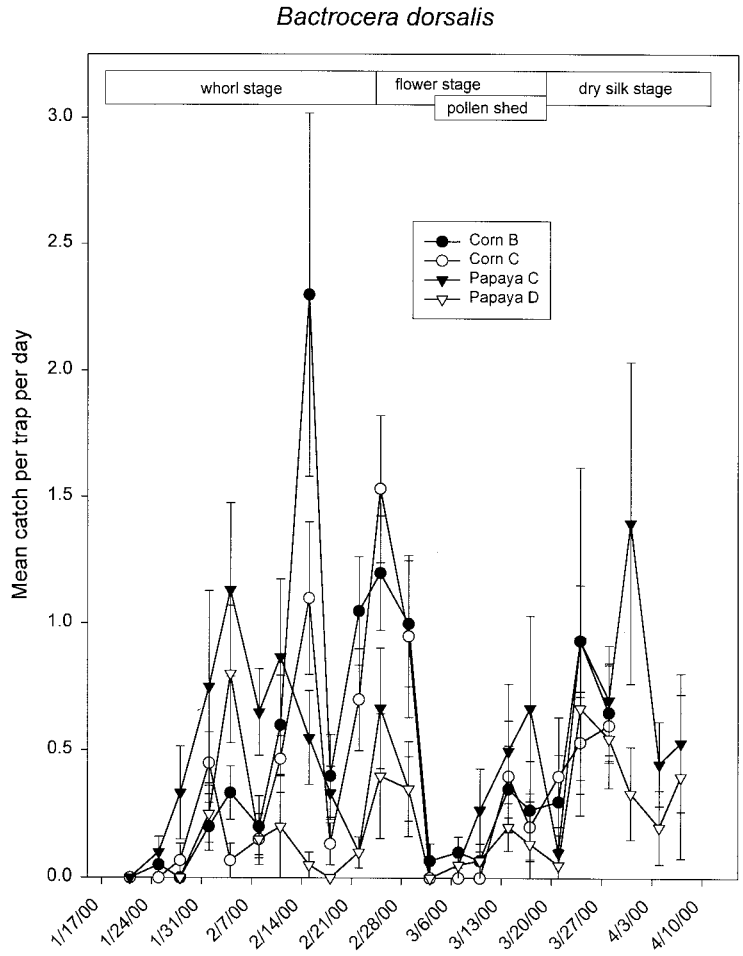

Fig. 6. Average catch per trap per day of *B. dorsalis* adults recovered from Corn B and Corn C, and papaya orchards in their vicinity, throughout the change in corn phenology from early whorl stage to the end of the dry silk stage.

Even though corn pollen appears to be attractive to melon flies, it is not as attractive as protein baits. In our fecundity tests, melon flies were observed to respond strongly to newly added ICN yeast hydrolysate powder but not to newly added corn pollen. However, there could be a stronger response to freshly shed pollen, relative to the pollen source used in this study. Such response, though, is still unlikely to exceed the attractiveness of a good protein bait.

The evidence we present for the use of corn pollen as a food source of two tephritid fruit fly species suggests that a dipteran specific Bt corn could be planted as a border crop as part of an overall integrated pest management (IPM) strategy for control of melon fly. An isolate of *Bacillus thuringiensis* (Berliner) subspecies *darmstadiensis* was toxic to adults of the Mexican fruit fly, *Anastrepha ludens* (Loew), when fed in a mixture of the bacterium, a protein source, and sugar (Martinez et al. 1997). If a Bt corn variety was developed from this Bt subspecies, the pollen, potentially, would be toxic to tephritid fruit flies, such as the melon fly and the oriental fruit fly. There are, however, many questions as to whether this is an appropriate strategy, an economically realistic strategy, or even an environmentally sound strategy. If a dipteran specific Bt corn was developed, the potential impact of the pollen on adults of other dipteran species, and other organisms that forage in corn environments, would need to be researched. The recent attention directed to the possible adverse effects of Bt corn pollen on nontarget lepidoptera (Losey et al. 1999) shows the potential risk of these new technologies. To date, Bt corn strains have been developed to minimize pest damage that adversely impacts corn yield. It would be a unique approach to develop a Bt corn strain with the sole intent to control an insect that is not a pest of corn and thereby has no impact on corn yield. The economic return for development of such a strain would be its suppressive effect on fruit fly infestations in other crops and not in the corn itself.

It should be noted that the trends observed in this research seem to be weather-dependent. At times of higher rainfall rates during the pollen shed stage or beyond, pollen can be washed off the leaves and this

seems to stop population increases in corn (G.T.M., unpublished data).

Earlier research (Nishida and Bess 1957) has shown corn to be an attractive plant for *B. cucurbitae*, but it was not noted to be attractive also for *B. dorsalis.* Our research shows corn to be attractive to *B. dorsalis*, also. This attraction, though, seems to be less than for *B. cucurbitae.* The survivorship test results suggest that corn pollen may better provide nutrients needed by *B. cucurbitae* adults than by *B. dorsalis* adults. This may be a factor in the lower level of attraction of *B. dorsalis* to corn. In control programs for either or both species, it is important to recognize that both species show some attraction to corn and that this attraction may increase during, and subsequent to pollen-shed.

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